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(54) **A hermetically sealed sensor with a movable microstructure**

Hermetisch abgeschlossener Sensor mit beweglicher Mikrostruktur

Capteur scellé hermétiquement avec microstructure mobile

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US-A- 5 164 328

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Description

[0001] The present invention relates to a sensor with a movable microstructure and, in particular, to a sensor according to the preamble of the first claim.

[0002] Sensors with movable microstructures such as, for example, inertial sensors which can measure a physical quantity relating to a movement of the sensor and produce an output signal dependent on the quantity are used in various applications, for example, in the automotive field for monitoring various devices such as air bags, anti-slip braking systems (ABS), and active suspensions, or in other fields such as consumer electronics, computers and the like. Sensors with movable microstructures are formed on a microscopic scale in chips of semiconductor material; a sensor of this type comprises a sensitive element which can produce an electrical signal relating to the movement of a microstructure movable relative to a surface of the chip.

[0003] In sensors with movable microstructures, the sensitive element has to be suitably protected by being enclosed in a hermetic structure to ensure that it operates in a controlled environment; this allows the microstructure of the sensitive element, which has a very small mass, to move with little resistance and minimal damping so as to ensure good sensitivity of the sensor. A sensor of this type also includes a circuitry which processes the electrical signal generated by the sensitive element and which, in turn, has to be encapsulated in a suitable container (package) which protects the processing circuit from external environmental conditions, ensuring that it operates correctly.

[0004] A known technique for protecting a sensor with a movable microstructure consists in the encapsulation of the sensitive element and the processing circuitry in a hermetic, for example, ceramic or metal package; the sensitive element and the processing circuitry can thus be incorporated in the same semiconductor chip. However, this technique is extremely expensive, resulting in a high final product cost.

[0005] A different known technique consists in the production of a hollow structure on a microscopic scale (a micro-cavity) which houses the sensitive element. This isolation method involves micromachining of a silicon or glass chip which is then connected to the chip on which the sensitive element is formed, for example, by an anodic bonding technique; this technique allows inexpensive standard plastics packages to be used for encapsulating the final product. However, the known solution described above is quite complex and expensive. Moreover, this technique does not allow the sensitive element and the processing circuitry to be incorporated in the same chip since the bonding step requires the surfaces to be joined to be perfectly flat (with a peak-valley roughness of the order of a hundred Å); generally, the plate containing the sensitive element and that containing the processing circuitry are arranged side by side and are connected electrically by means of suitable metal wires.

[0006] The sensitive elements of sensors with movable microstructures are usually made in large numbers in several identical areas of a wafer of semiconductor material which are subsequently separated by a suitable cutting operation. The cutting is generally carried out by means of a high-velocity, water-cooled, diamond-blade saw. A further disadvantage of the known sensors is that, during the drying of the water used for cooling the blade, permanent sticking or "stiction" of the movable high-velocity, water-cooled, diamond-blade saw. A further disadvantage of the known sensors is that, during the drying of the water used for cooling the blade, permanent sticking or "stiction" of the movable microstructure to an underlying surface of the semiconductor chip may occur. This physical phenomenon renders the sensor unusable.

[0007] Document US-5164328 discloses a method of joining an integrated circuit die and a sensor die by the use of solder bumps for the formation of a hybrid circuit assembly. According to this document a dielectric sealant is deposited around the outside edges of the sensor to prevent foreign material such as encapsulating material from interfering with the operation of the sensor.

[0008] Document EP-773443-A1 describes micromechanical acceleration sensor consisting of two semiconductor wafers and having a cavity housing movable electrodes. This cavity is provided with lateral walls made by silicon layers overlapped to metal layers.

[0009] The object of the present invention is to prevent the aforementioned drawbacks. To achieve this object, a sensor with a movable microstructure as described in the first claim is proposed.

[0010] The sensor with a movable microstructure according to the present invention is particularly compact, simple and inexpensive.

[0011] This sensor permits the optional use of a plastics, and hence extremely inexpensive, package for encapsulating the final product.

[0012] The method of producing the sensor of the present invention does not require micromachining of a further silicon or glass wafer or connection thereof to the wafer on which the sensitive elements are formed. Moreover, both of the semiconductor chips used in the structure of the present invention contain active elements (the sensitive element and the processing circuitry, respectively) so that there is no wastage of material.

[0013] Further characteristics and the advantages of the sensor with a movable microstructure according to the present invention will become clear from the following description of a preferred embodiment thereof, given by way of non-limiting example, with reference to the sole appended drawing (Figure 1) which shows the sensor in a partially-sectioned schematic view.

[0014] The drawing shows a sensor 100 having a movable microstructure and constituted, in particular, by an inertial sensor comprising a sensitive element 105 which can detect a physical quantity relating to the inertia of one or more movable microstructures and can produce a corresponding electrical signal. The sensitive element 105 includes, for example, a micro-mechanical structure (a micro-electromechanical structure, or MEMS) formed on an upper surface of a chip 110 of semiconductor material, typically silicon. The sensitive element 105 generally has a so-called seismic mass anchored to the chip 110 at predetermined points and movable relative thereto, its movement being converted into a suitable electrical signal. For example, the seismic mass may constitute a first electrode of a capacitor the second electrode of which is provided on the chip 110; the movement of the seismic mass brings about a change in the capacitance of the capacitor which in turn is measured by a suitable circuit. The sensor 100 is, for example, an accelerometer, an angular velocity sensor (a gyroscope) or a vibration sensor, in which the microstructure of the sensitive element 105 moves as a result of the linear/angular acceleration or of the angular velocity of a system (for example, a motor-car) on which it is mounted, enabling the desired physical quantity to be measured; in alternative embodiments of the present invention, the sensor is a resonant sensor in which the movable microstructure of the sensitive element vibrates at a frequency which varies in dependence on the quantity to be detected, etc.

[0015] The sensitive element 105 is sealed within a hollow hermetic structure 115 which protects the sensitive element 105 from microscopic particles and from damage resulting from assembly operations, as well as ensuring leaktightness with respect to an internal gas (for example, air or nitrogen, typically at a pressure lower than atmospheric pressure) for regulating the damping of the movable microstructure of the sensitive element 105. In the sensor 100 of the present invention, the hollow hermetic structure 115 is defined laterally by a metal wall 120 (formed, for example, of aluminium, nickel, copper, or the like) which is disposed on the upper surface of the chip 110 around the sensitive element 105, and the shape (for example, circular or rectangular) of which varies according to the shape of the sensitive element 105. The hollow hermetic structure 115 is closed at the top by means of a further chip of semiconductor material 125 (having a size at least equal to that of the hermetic cavity 115) which is fixed to the wall 120. A circuitry 130 for processing the electrical signal produced by the sensitive element 105 is integrated in the semiconductor chip 125 and, for example, can amplify, control, compensate, and calibrate the signal. It should be noted that the movable microstructure (enclosed in a metal cavity) is advantageously screened from electromagnetic interference, for example, by the connection of the chip 125 to a reference terminal or to earth.

[0016] Contact electrodes formed on the upper surface of the chip 110, which is covered with an insulating layer 135 (typically silicon dioxide), are constituted by one or more conductive pads 140, 142 (four in the embodiment shown in the drawing) arranged inside the hollow hermetic structure 115 and by one or more conductive pads 145 (two in the embodiment shown in the drawing) arranged outside the hollow hermetic structure 115. Similarly, contact electrodes constituted by one or more pads 155 and 156 (four in the embodiment shown in the drawing) are formed on the lower surface of the chip 125, which is covered by an insulating layer 150. Each of the pads 155, 156 formed on the chip 125 is arranged facing and connected to a corresponding pad 140, 142 formed on the chip 110. The pads 140 are connected electrically to the sensitive element 105 in order to transmit the electrical signal generated by the sensitive element 105 to the corresponding pads 155 and hence to the processing circuitry 130; the connection between the sensitive element 105 and the pads 140 is achieved, for example, by means of low-resistance diffusion brought about in the semiconductor chip 110 (before or after the growth of an epitaxial layer) or by means of metal connections at a level below that at which the metal wall 120 is formed. The electrical signal processed by the circuitry 130 is transferred to the pads 142 by means of the corresponding pads 156. The pads 142 are connected electrically to the pads 145 in a similar manner in order to transmit the processed electrical signal to an external circuit. The present invention may, however, also be implemented with different methods of electrical connection between the chip containing the sensitive element and the chip containing the processing circuit. For example, the contact electrodes connected to the sensitive element are arranged outside the hermetic cavity and the contact electrodes connected to the processing circuitry are arranged on the upper surface of the respective chip and then connected by means of metal wires.

[0017] The sensor 100 described above is produced starting with a first semiconductor wafer on an upper surface of which a large number of sensitive elements 105 is formed by known micromachining techniques. A metallic aluminium layer (typically 1 μm thick) is deposited on the entire upper surface of the wafer and the pads 140, 142, 145 and a lower frame 160, used (as described below) for forming the metal wall 120, are defined therein by known masking and selective etching techniques; the wafer is then covered with the insulating layer 135 in which openings or windows are similarly formed in the regions of the pads 140, 142, 145 and of the lower frame 160. A thin layer (a flash) of gold which protects against oxidation and improves the quality of the welding is preferably deposited on the pads 140, 142, 145 and on the lower frame 160.

[0018] A large number of processing circuits 130 corresponding to the sensitive elements 105 is formed in a second wafer by known integration techniques. The pads 155, 156 and an upper frame 165 used (as described below) to define the metal wall 120 are then formed in the manner described above. The invention may, however, also be implemented with the metal wall 120 formed entirely on a single wafer.

[0019] In a particular embodiment of the present invention, the upper frame 165 (or alternatively, the lower frame 160

or both of the frames 160, 165) is subjected to a growth process in order to increase its thickness (similar remarks apply to the pads 140, 142 and 155, 156 which have to be connected to one another within the hollow hermetic structure 115). This additional step is useful when the height of the metal wall 120 produced by the process described above (generally 2-3μm) is not sufficient to ensure correct movement of the microstructure of the sensitive element 105. In particular, a projection (a bump) made, for example of nickel or copper, is grown on the upper frame 165 (and on the pads 155 and 156). This bump is formed by means of a non-electrolytic (electroless) growth process. In detail, a layer of more noble metal, for example zinc, is deposited and prevents the formation of oxide and hydroxide layers on the aluminium. The wafer is then immersed in an autocatalytic chemical solution in order to grow a layer of nickel; finally, a thin layer (a flash) of gold which protects against oxidation and improves the quality of the welding, is deposited. The process described above is particularly inexpensive and flexible since it is compatible with machining of the wafers in batches and does not require any additional masks. Alternatively, electro-deposition (electroplating), evaporation, or dispensing methods, and the like, are used.

[0020] The wafer containing the processing circuitry 130 is then cut to form the various chips 125. The chips 125 are fixed to the wafer (as yet uncut) containing the sensitive elements 105. In particular, the upper frame 165 and the pads 155,156 of each plate 125 are fixed to a corresponding lower frame 160 and to the corresponding pads 140, 142, respectively. For this purpose, a welding process, for example, a thermal compression process, in which the heated parts are joined simply by pressure, or a thermal-ultrasonic process which provides for the simultaneous application of heat and ultrasound, is preferably used; alternatively, the fixing is achieved by different techniques, for example, with the use of a suitable adhesive.

[0021] Upon completion of the operations on the wafer containing the sensitive elements 105 (and the respective checking) this wafer is cut to form the various chips 110. The sensitive elements 105 are thus protected in the hollow hermetic structure 115 so that they are not damaged during the cutting operation and are not exposed to the danger of "stiction". This enables an extremely high production yield to be achieved.

[0022] The production of the sensor is then completed by known and conventional operations. Each chip 110 is fixed to a suitable frame by soldering with an alloy having a low melting point, for example, lead-tin, or by gluing with a suitable adhesive. The pads 145 are connected to the corresponding electrodes by means of thin metal, for example, gold wires; typically, the metal wires are soldered to the pads 145 on the one hand and to the inner ends of the electrodes on the other hand with an alloy having a low melting point, by a thermal-ultrasonic method. The unit thus produced can be used directly if it is fitted in a system in a controlled environment, as in hard-disk drivers. Alternatively, the unit is mounted in a suitable die into which a plastics material, for example, a thermosetting epoxy resin, is injected in the liquid state. After polymerization of the resin, a device comprising an insulating body which incorporates the elements described above and from which the electrodes project for connection to an external circuit is thus produced. The sensor of the present invention may, however, also be used in different devices, for example, ball-grid array (or BGA) devices and the like.

[0023] Naturally, in order to satisfy contingent and specific requirements, an expert in the art may apply to the above-described sensor with a movable microstructure many modifications and variations all of which, however, are included within the scope of protection of the invention as defined by the following claims.

Claims

1. A sensor (100) with a movable microstructure, comprising a sensitive element (105), entirely formed in a first chip (110) of semiconductor material, for producing an electrical signal dependent on a movement of at least one movable microstructure relative to a surface of the first chip (110), the sensitive element (105) being enclosed in a hollow hermetic structure (115), a circuit (130) for processing said electrical signal, formed in a second chip (125) of semiconductor material, and means (140,155) electrically connecting the first (110) and second (125) chip for transmitting the electrical signal from the sensitive element (105) to the processing unit (130), **characterized in that** the hollow hermetic structure (115) includes a metal wall (120) disposed on the surface of the first chip (110) around the sensitive element (105) and the second chip (125) being fixed to said wall (120), the metal wall (120) extending from the first chip (110) to the second chip (125) for laterally defining the hollow hermetic structure (115).

2. A sensor (100) according to Claim 1, in which the metal wall (120) is made substantially of nickel.

3. A sensor (100) according to Claim 1 or Claim 2, wherein the electrically connecting means (140,155) comprises at least one first conductive pad (140) formed on the surface of the first chip (110) within the hollow hermetic structure (115) and connected electrically to the sensitive element (105), each first pad (140) being connected to a second, facing conductive pad (155) formed on a surface of the second chip (125) and electrically connected to the processing circuit (130).

4. A sensor (100) according to Claim 3, further comprising at least one third conductive pad (142) formed on the surface of the first chip (110) within the hollow hermetic structure (115), each third pad (142) being connected to a fourth, facing conductive pad (156) formed on the surface of the second chip (125) for receiving an electrical signal processed by the processing circuit (130).

5. A sensor (100) according to Claim 4, further comprising at least one fifth conductive pad (145) formed on the surface of the first chip (110) outside the hollow hermetic structure (115), each fifth pad (145) being connected electrically to a corresponding third pad (142) for transmitting the processed electrical signal to the exterior.

6. A sensor (100) according to any one of Claims 1 to 5, in which the sensor (100) is an inertial sensor.

7. An electronic device comprising the sensor (100) of any one of Claims 1 to 6 and a plastics package in which the sensor (100) is encapsulated.

8. A method of producing sensors (100) with movable microstructures, comprising the steps of:

a) forming, entirely in a first wafer of semiconductor material, a plurality of sensitive elements (105) each for producing an electrical signal dependent on a movement of at least one microstructure movable relative to a surface of the first wafer,
b) forming a first metal frame (160) on the surface of the first wafer around each of the sensitive elements (105),
c) forming, in a second wafer of semiconductor material, a plurality of circuits (130) for processing the electrical signal,
d) forming, on a surface of the second wafer, a second metal frame (165) corresponding to each of the first frames (160),
e) cutting the second wafer to produce a plurality of chips of semiconductor material (125) each containing one of the processing circuits (130) and one of the second frames (165),
f) fixing the second frame (165) of each chip (125) to the corresponding first frame (160) in order to enclose the sensitive element (105) in a hollow hermetic structure (115) said first and second frame forming a metal wall (120) extending from the first chip (110) to the second chip (125) and laterally defining the hollow hermetic structure (115),
g) electrically connecting each chip (125) to the first wafer for transmitting the electrical signal from each sensitive element (105) to the corresponding processing circuit (130).

9. A method according to Claim 8, in which step f) is carried out by means of a welding process.

10. A method according to Claim 8 or Claim 9, further comprising, before step e), the step of growing a metal bump on the second frames (165).

11. A method according to Claim 10, in which the step of growing the metal bump is carried out by means of a non-electrolytic growth process.

Patentansprüche

1. Ein Sensor (100) mit einer bewegbaren Mikrostruktur, mit einem empfindlichen Element (105), das vollständig in einem ersten Chip (110) eines Halbleitermaterials gebildet ist, zum Erzeugen eines elektrischen Signals abhängig von einer Bewegung von zumindest einer bewegbaren Mikrostruktur relativ zu einer Oberfläche des ersten Chips (110), wobei das empfindliche Element (105) in einer hohlen hermetischen Struktur (115) eingeschlossen ist, einer Schaltung (130) zum Verarbeiten des elektrischen Signals, die in einem zweiten Chip (125) eines Halbleitermaterials gebildet ist, und einer Einrichtung (140, 155), die den ersten (110) und zweiten (125) Chip elektrisch verbindet, zum Übertragen des elektrischen Signals von dem empfindlichen Element (105) zu der Verarbeitungseinheit (130), **dadurch gekennzeichnet, dass** die hohle hermetische Struktur (115) eine Metallwand (120) umfasst, die auf der Oberfläche des ersten Chips (110) um das empfindliche Element (105) angeordnet ist, und dass der zweite Chip (125) an der Wand (120) befestigt ist, wobei die Metallwand (120) sich von dem ersten Chip (110) zu dem zweiten Chip (125) erstreckt, um lateral die hohle hermetische Struktur (115) zu definieren.

2. Ein Sensor (100) gemäß Anspruch 1, bei dem die Metallwand (120) im Wesentlichen aus Nickel hergestellt ist.

3. Ein Sensor (100) gemäß Anspruch 1 oder Anspruch 2, bei dem die elektrische Verbindungseinrichtung (140, 155) zumindest eine erste leitfähige Anschlussfläche (140) aufweist, die auf der Oberfläche des ersten Chips (110) innerhalb der hohlen hermetischen Struktur (115) gebildet ist und elektrisch mit dem empfindlichen Element (105) verbunden ist, wobei jede erste Anschlussfläche (140) mit einer zweiten, derselben zugewandten, leitfähigen Anschlussfläche (155) verbunden ist, die auf einer Oberfläche des zweiten Chips (125) gebildet ist und elektrisch mit der Verarbeitungsschaltung (130) verbunden ist.

4. Ein Sensor (100) gemäß Anspruch 3, der ferner zumindest eine dritte leitfähige Anschlussfläche (142) aufweist, die auf der Oberfläche des ersten Chips (110) innerhalb der hohlen hermetischen Struktur (115) gebildet ist, wobei jede dritte Anschlussfläche (142) mit einer vierten, derselben zugewandten, leitfähigen Anschlussfläche (156) verbunden ist, die auf der Oberfläche des zweiten Chips (125) gebildet ist, um ein elektrisches Signal zu empfangen, das durch die Verarbeitungsschaltung (130) verarbeitet wird.

5. Ein Sensor (100) gemäß Anspruch 4, der ferner zumindest eine fünfte leitfähige Anschlussfläche (145) aufweist, die auf der Oberfläche des ersten Chips (110) außerhalb der hohlen hermetischen Struktur (115) gebildet ist, wobei jede fünfte Anschlussfläche (145) elektrisch mit einer entsprechenden dritten Anschlussfläche (142) verbunden ist, um das verarbeitete elektrische Signal nach außen zu übertragen.

6. Ein Sensor (100) gemäß einem der Ansprüche 1 bis 5, wobei der Sensor (100) ein inertialer Sensor ist.

7. Eine elektrische Vorrichtung, die den Sensor (100) gemäß einem der Ansprüche 1 bis 6 und ein Kunststoffgehäuse aufweist, in dem der Sensor (100) eingeschlossen ist.

8. Ein Verfahren zum Herstellen von Sensoren (100) mit einer bewegbaren Mikrostruktur, das folgende Schritte aufweist:

   a) Bilden, vollständig in einem ersten Wafer eines Halbleitermaterials, einer Mehrzahl von empfindlichen Elementen (105), jedes zum Herstellen eines elektrischen Signals abhängig von einer Bewegung von zumindest einer Mikrostruktur, die relativ zu einer Oberfläche des ersten Wafers bewegbar ist,
   b) Bilden eines ersten Metallrahmens (160) auf der Oberfläche des ersten Wafers um jedes der empfindlichen Elemente (105) herum,
   c) Bilden, in einem zweiten Wafer eines Halbleitermaterials, einer Mehrzahl von Schaltungen (130) zum Verarbeiten des elektrischen Signals,
   d) Bilden, auf einer Oberfläche des zwelen Wafers, eines zweiten Metallrahmens (165), der jedem der ersten Rahmen (160) entspricht,
   e) Schneiden des zweiten Wafers, um eine Mehrzahl von Chips aus Halbleitermaterial (125) zu erzeugen, wobei jeder eine der Verarbeitungsschaltungen (130) und einen der zweiten Rahmen (165) enthält,
   f) Befestigen des zweiten Rahmens (165) jedes Chips (125) an dem entsprechenden ersten Rahmen (160), um das empfindliche Element (105) in einer hohlen hermetischen Struktur (115) einzuschließen, wobei der erste und der zweite Rahmen eine Metallwand (120) bilden, die sich von dem ersten Chip (110) zu dem zweiten Chip (125) erstreckt und lateral die hohle hermetische Struktur (115) definiert,
   g) elektrisches Verbinden jedes Chips (125) mit dem ersten Wafer zum Übertragen des elektrischen Signals von jedem empfindlichen Element (105) zu der entsprechenden Verarbeitungsschaltung (130).

9. Ein Verfahren gemäß Anspruch 8, bei dem Schritt f) mit Hilfe eines Schweißprozesses ausgeführt wird.

10. Ein Verfahren gemäß Anspruch 8 oder Anspruch 9, das ferner vor Schritt e) den Schritt zum Aufwachsen eines Metallhügels auf den zweiten Rahmen (165) aufweist.

11. Ein Verfahren gemäß Anspruch 10, bei dem der Schritt des Aufwachsens des Metallhügels mit Hilfe eines nichtelektrolytischen Aufwachsprozesses ausgeführt wird.

Revendications

1. Capteur (100) muni d'une microstructure mobile, comprenant un élément sensible (105), entièrement formé dans une première puce (110) de matériau semi-conducteur, afin de produire un signal électrique dépendant d'un mouvement d'au moins une microstructure mobile par rapport à une surface de la première puce (110), l'élément sensible

(105) étant enfermé dans une structure hermétique creuse (115), un circuit (130) destiné à traiter ledit signal électrique, formé dans une seconde puce (125) en matériau semi-conducteur, et des moyens (140, 155) reliant électriquement la première (110) et la seconde (125) puces afin de transmettre le signal électrique entre l'élément sensible (105) et l'unité de traitement (130), **caractérisé en ce que** la structure hermétique creuse (115) comprend une paroi métallique (120) disposée sur la surface de la première puce (110) autour de l'élément sensible (105) et la seconde puce (125) étant fixée sur ladite paroi (120), la paroi métallique (120) s'étendant entre la première puce (110) et la seconde puce (125) afin de définir latéralement la structure hermétique creuse (115).

2. Capteur (100) selon la revendication 1, dans lequel la paroi métallique (120) est fabriquée pour l'essentiel en nickel.

3. Capteur (100) selon la revendication 1 ou la revendication 2, dans lequel les moyens de liaison électrique (140, 155) comprennent au moins une première plage conductrice (140) formée sur la surface de la première puce (110) dans la structure hermétique creuse (115) et reliée électriquement à l'élément sensible (105), chaque première plage (140) étant reliée à une seconde plage conductrice située en face (155) et formée sur une surface de la seconde puce (125), et reliée électriquement au circuit de traitement (130).

4. Capteur (100) selon la revendication 3, comprenant en outre au moins une troisième plage conductrice (142) formée sur la surface de la première puce (110) dans la structure hermétique creuse (115), chaque troisième plage (142) étant reliée à une quatrième plage conductrice située en face (156) et formée sur la surface de la seconde puce (125) afin de recevoir un signal électrique traité par le circuit de traitement (130).

5. Capteur (100) selon la revendication 4, comprenant en outre au moins une cinquième plage conductrice (145) formée sur la surface de la première puce (110) à l'extérieur de la structure hermétique creuse (115), chaque cinquième plage (145) étant reliée électriquement à une troisième plage correspondante (142) afin de transmettre le signal électrique traité vers l'extérieur.

6. Capteur (100) selon l'une quelconque des revendications 1 à 5, dans lequel le capteur (100) est un capteur à inertie.

7. Dispositif électronique comprenant le capteur (100) selon l'une quelconque des revendications 1 à 6 et un emballage en plastique dans lequel le capteur (100) est encapsulé.

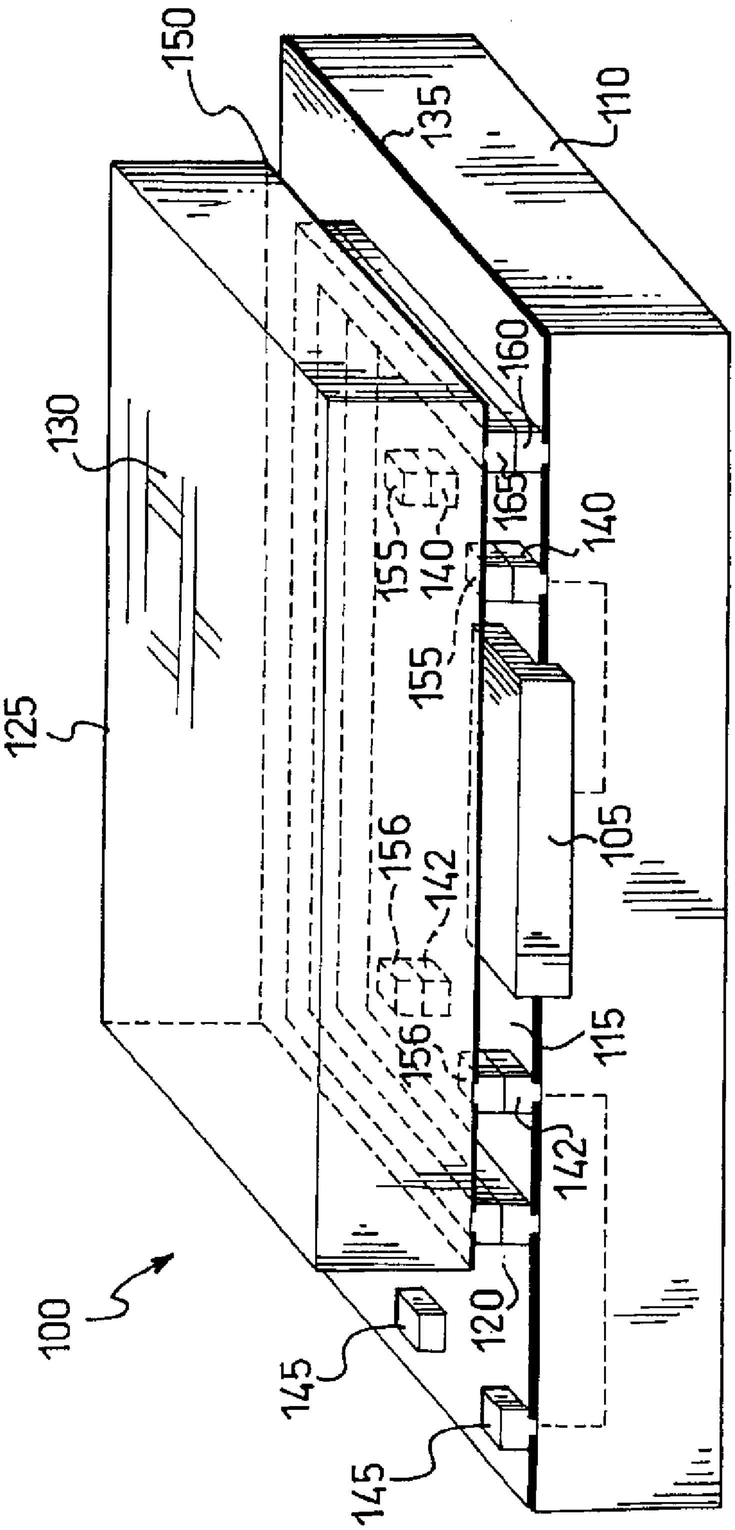
8. Procédé de production de capteurs (100) avec des microstructures mobiles, comprenant les étapes consistant à :

   a) former, entièrement dans une première couche de matériau semi-conducteur, une pluralité d'éléments sensibles (105) destinés chacun à produire un signal électrique dépendant d'un mouvement d'au moins une microstructure mobile par rapport à une surface de la première couche,
   b) former une première armature métallique (160) sur la surface de la première couche, autour de chacun des éléments sensibles (105),
   c) former, dans une seconde couche du matériau semi-conducteur, une pluralité de circuits (130) destinés à traiter le signal électrique,
   d) former, sur une surface de la seconde couche, une seconde armature métallique (165) correspondant à chacune des premières armatures (160),
   e) découper la seconde couche afin de produire une pluralité de puces en matériau semi-conducteur (125), contenant chacune l'un des circuits de traitement (130) et l'une des secondes armatures (165),
   f) fixer la seconde armature (165) de chaque puce (125) sur la première armature correspondante (160) afin d'enfermer l'élément sensible (105) dans une structure hermétique creuse (115), lesdites première et seconde armatures formant une paroi métallique (120) s'étendant entre la première puce (110) et la seconde puce (125) et définissant latéralement la structure hermétique creuse (115),
   g) relier électriquement chaque puce (125) à la première couche afin de transmettre le signal électrique provenant de chaque élément sensible (105) vers le circuit de traitement correspondant (130).

9. Procédé selon la revendication 8, dans lequel l'étape f) est réalisée à l'aide d'un processus de soudage.

10. Procédé selon la revendication 8 ou la revendication 9, comprenant en outre, avant l'étape e), l'étape consistant à développer une bosse métallique sur les secondes armatures (165).

11. Procédé selon la revendication 10, dans lequel l'étape consistant à développer la bosse métallique est réalisée à l'aide d'un processus de développement non électrolytique.



100
145
145
120
142
156
115
156
142
105
125
155
155
140
140
165
160
130
150
135
110

FIG.1